9-12: Earth's Energy Budget-Seasonal Cycles Lesson Plan

Purpose:

Students move through a series of short activities to explore and evaluate global solar radiation data from NASA satellites. In this process, students make qualitative and quantitative observations about seasonal variations in net energy input to the Earth system.

<table>
<tr>
<td>Grade Level: 9-12
Time: 90 minutes
MND Lesson # 44</td>
<td>Lesson Objectives:
Use evidence to create an explanation.
Observe the seasonal changes to explain the phenomenon of Earth's tilt and incoming solar energy.</td>
<td>Sphere(s):
Atmosphere
Hydrosphere</td>
</tr>
<tr>
<td colspan="3">Phenomena NASA Connection:
The Sun's radiation and its interactions with the Earth system is the foundation of the global climate system underscoring the importance of the relationships with the Sun's radiation in the Atmosphere, ocean, and land. Global climate models, developed by scientists and mathematicians, are used to predict future changes, including changes related to human impacts and natural factors. Using GLOBE and MY NASA DATA educators and students can access NASA satellite data to examine a variety of Earth system interactions. In this lesson, Earth's Energy Budget-Seasonal Cycles, students move through a series of short activities to explore and evaluate Net Radiative Flux data from NASA satellites. In this process, students make qualitative and quantitative observations about seasonal variations in net energy input to the Earth system during the year of 2015.</td>
</tr>
<tr>
<td colspan="3">Essential Questions:
How does energy flow in and among the spheres within the Earth System?
What does it mean that the atmosphere is in a "dynamic balance?"
How do changes in one part of the Earth system affect other parts of the system?</td>
</tr>
<tr>
<td colspan="3">NGSS Performance Expectation(s):
HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts on Earth systems.</td>
</tr>
<tr>
<td>Science Practices:
Asking Questions and Defining Problems: Ask questions to identify and clarify evidence of an argument.
Developing and Using Models: Develop and use a model to describe phenomena.
Analyzing and Interpreting Data: Analyze data using computational models in order to make valid and reliable scientific claims.</td>
<td>Disciplinary Core Idea:
ESS2.A: Earth Materials and Systems
ESS1.B: Earth and the Solar System
ESS2.D: Weather and Climate
ESS3.D Global Climate Change</td>
<td>Crosscutting Concepts:
Energy and Matter
Stability and Change
Cause and Effect
Systems and System Models</td>
</tr>
</table>

NCTM Math Standards: n/a

Cross-Curricular Connections:
National Geography Standards:
1. How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
7. The physical processes that shape the patterns of Earth's surface.

Career Connections:
Visit the *Why Science: Yolanda Shea* online article (https://www.nasa.gov/feature/langley/why-science-yolanda-shea) for a NASA employee who serves as Research Scientist at Langley Research Center, Hampton, VA.

Scientists:
- **Atmospheric and Space Scientists** - Investigate weather and climate related phenomena to prepare weather reports and forecasts for the public
- **Computer and Information Scientists** - Conduct research in the field of computer and information science
- **Remote Sensing Scientists and Technologists** - Research a variety of topics using techniques that allow the study of an object or phenomena without making contact directly with the object such as analyzing geological and geographical data. They typically work with aerial or satellite pictures.

Multimedia Resources:
- Striking a Solar Balance (https://youtu.be/uTUJI-O6VvY)
- Animation of Earth Net Radiative Flux (https://eoimages.gsfc.nasa.gov/images/globalmaps/data/mov/CERES_NETFLUX_M.mov)

Materials:
Per Student:
- Student Datasheet

Per Group
- Student Pages: Monthly TOA All-Sky Net Radiative Flux for Jan & March 2015 - July 2015

Key Vocabulary:
- radiation
- short wave
- long wave
- net flux

Background Information:

Some of the sunlight that reaches Earth is reflected back to space by bright surfaces like clouds or ice. The rest is absorbed by the atmosphere, oceans, and land. This absorbed light is converted to heat, which the surface and atmosphere emit back to space. "Net radiation" is the total amount of absorbed sunlight and heat energy that does not escape from the top of the Earth's atmosphere back into space. Specifically, net radiation is the sum total of shortwave and longwave electromagnetic energy at wavelengths ranging from 0.3 to 100 micrometers that remain in the Earth system. The net radiation is the energy that is available to influence the climate. If the net radiation on a global scale is not zero, the planet's overall temperature will rise or fall.

Regions of positive net radiation have an energy surplus, and areas of negative net radiation have an energy deficit. False-color maps represent the net radiation,in Watts per square meter, that was contained in the Earth system for a given time period.The maps illustrate the fundamental imbalance between net radiation surpluses at the equator, where sunlight is direct year-round, and net radiation deficits at high latitudes, where direct sunlight is seasonal. This imbalance is the fundamental force that drives atmospheric and oceanic circulation patterns.

Accurate estimates of the top of the atmosphere (TOA) and surface radiative budgets combine to close the atmospheric radiative budget and improve calculations of implied heat transports within the Earth-atmosphere system. The net surface shortwave (SW) and longwave (LW) fluxes affect the heating/cooling of the surface and act to bind sensible and latent heat fluxes, as well as horizontal oceanic and atmospheric heat transport. The amount of solar energy and moisture at the Earth's surface determine its ability to sustain life processes, and these life processes act to affect the net fluxes. Changes in input of energy to surface systems (oceans, land surface including ecosystems and cryosphere) have effects on short and long-term weather and climate related processes. Sudden changes in surface reflective/emissive properties, such as those caused by a retreating ice/snow layer, have profound effects on net fluxes at the surface and may cause regional feedbacks. Additionally, changes in cloudiness, aerosols, and gaseous profiles also regulate the surface fluxes in important ways. Finally, the quality of human life is affected by solar energy and thermal infrared energy exchange at the surface by its effective use as an energy source and its implications on hydrological and biological processes.

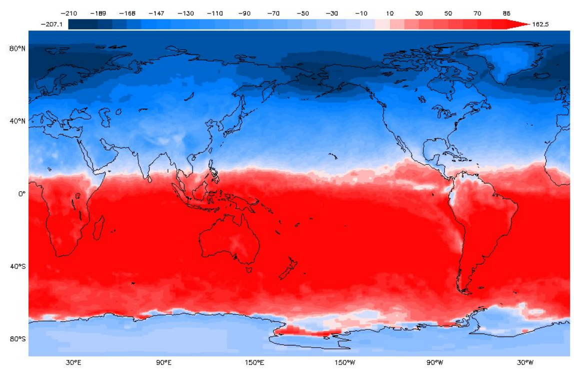
Prerequisite Student Knowledge:
- Familiarity with locating given geographical locations using latitude and longitude and a world map
- Familiarity with seasons and Earth's tilt

Possible Misconceptions:
- "Where earth's axis of rotation points, with respect to a point in space, changes during the year."
- "The angle between the earth's axis and the plane of the earth's orbit around the sun changes throughout the year."
- "The orientation of earth's axis of rotation with respect to the sun does not change during the year."
- "The intensity of sunlight at a place does not change from day to day during the year."
- "The amount of time the sun is above the horizon at a given place does not change from day to day."

-**Taken from AAAS Science Links**

Procedure:

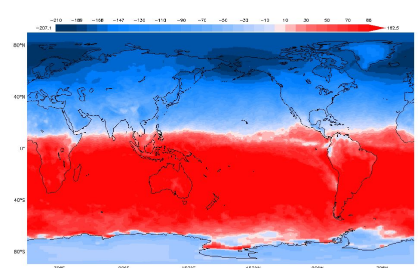
Part 1:



1. Display *Student Page* Monthly TOA All-Sky Net Radiative Flux for January 2015. Do not share the date of the image with students.
2. Have students brainstorm, journal, and share three qualitative and three quantitative observations.
   Possible answers may include, but not be limited to the following: (NOTE: It is hard to differentiate in the grayscale image; you may wish to project the colored image for whole class to view if color printer is unavailable).
   Qualitative: *e.g., 1.) There appears to be a balance of incoming and outgoing radiation at the Equator and at the northern edge of Antarctica. 2.) Antarctica is mostly losing radiation. 3.) Greenland is losing less radiation that its surrounding environments at its same latitude.*
   Quantitative: *1.) Around 10°N, there is a balance whereby there is an apparent balance among absorbing and reflecting energy. 2) The Southern Hemisphere falls mostly in the range of 30 - 162.5 W/m² . 3)The Northern Hemisphere falls mostly in the range of -30 to -207.1 W/m²*
3. Direct students to observe the color legend and its values.
   a. What could the false colors represent? units of measurement?

   b. What time of year do you think this image represents? Why?

Part 2:

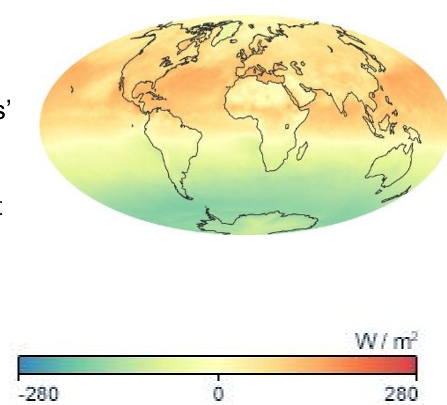


1. Again, review the Monthly TOA All-Sky Net Flux but tell students that this is an image captured by NASA satellites showing Atmospheric Radiation in January 2015.
   a. Knowing this date, how does this support or reject your ideas from earlier? *Answers will vary.*

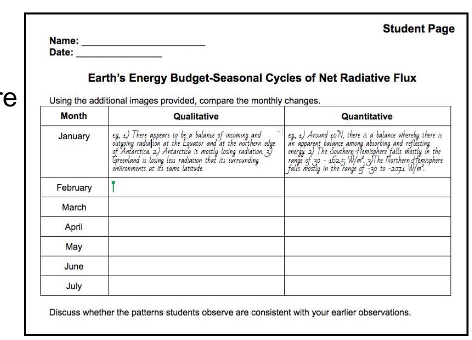
2. Explain that places in white represent areas where the amount of incoming and outgoing energy are in balance. (NOTE: It is hard to differentiate in the grayscale image; you may wish to project the colored image for whole class to view if color printer is unavailable).
    a. Places where more energy comes into the Earth System then goes out (positive net radiation) are red/dark gray. Places where more energy goes out then comes in (negative net radiation) are blue/white.
3. Distribute the Student Sheet. Allow students to work in teams or independently to answer the following questions:
    a. What systems are absorbing energy? *atmosphere, land surfaces and oceans*
    b. Where do you think more heat is being given off? What evidence do you have to support this?
    c. Where do you think there is more heat absorbed? What evidence do you have to support this claim?
    d. Now, distribute compare with the image from March 2015.
        i. What do you notice? *The red color is beginning to spread north, meaning that more solar energy is being absorbed in the Northern Hemisphere. The white areas are becoming more varied in location meaning that there is a balance of absorption and release.*
        ii. Where is energy being released than absorbed? *the Southern Ocean and Antarctica.*

Part 3:

1. Post the following questions for students to consider as they watch an animation:
    a. How does net radiation vary over the year at key months in the solar cycle.
    b. What are the key months where you see the most change?
2. Show [Animation of Earth Net Radiative Flux] and then review students' answers
    a. The maps and animation illustrate how net radiation varies over the year at key months in the solar cycle. In June, the tilt in Earth's rotational axis has its strongest influence on the amount of sunlight reaching the ground in each hemisphere. One hemisphere is tipped its farthest away from the Sun, and other is tipped toward it. Net radiation is strongly positive across the Northern Hemisphere in June, and strongly negative across the Southern Hemisphere. In December, the pattern reverses.



3. Show the following video- [Striking a Solar Balance] (https://youtu.be/uTUJI-O6VvY)



Student Page

Name: ____________________
Date: ______________

Earth's Energy Budget-Seasonal Cycles of Net Radiative Flux

Using the additional images provided, compare the monthly changes.

Month	Qualitative	Quantitative
January	e.g., 1) There appears to be a balance of incoming and outgoing radiation at the Equator and at the northern edge of Antarctica. 2) Antarctica is mostly losing radiation. 3) Greenland is losing less radiation that its surrounding environments at its same latitude.	e.g., 1) Around 10°N, there is a balance whereby there is an apparent balance among absorbing and reflecting energy. 2) The Southern Hemisphere falls mostly in the range of 30 - 162.5 W/m². 3) The Northern Hemisphere falls mostly in the range of -30 to -207.1 W/m².
February		
March		
April		
May		
June		
July		

Discuss whether the patterns students observe are consistent with your earlier observations.

Part 4:

1. Using the additional images provided on the Student Pages, compare the monthly changes. Note: The only Student Page with an unlabelled date is January 2015.
2. Discuss whether the patterns students observe are consistent with your earlier observations.

Student Page

Name: ______________________
Date: ________________

Earth's Energy Budget-Seasonal Cycles

Part 2: Using the additional images provided, compare the monthly changes.

1. What systems are absorbing energy?
2. Where do you think more heat is being given off? What evidence do you have to support this?
3. Where do you think there is more heat absorbed? What evidence do you have to support this claim?
    a. Review the image from March 2015.
    b. What do you observe?
    c. Where is energy being released than absorbed?

Part 4: Using the additional images provided, compare the monthly changes.

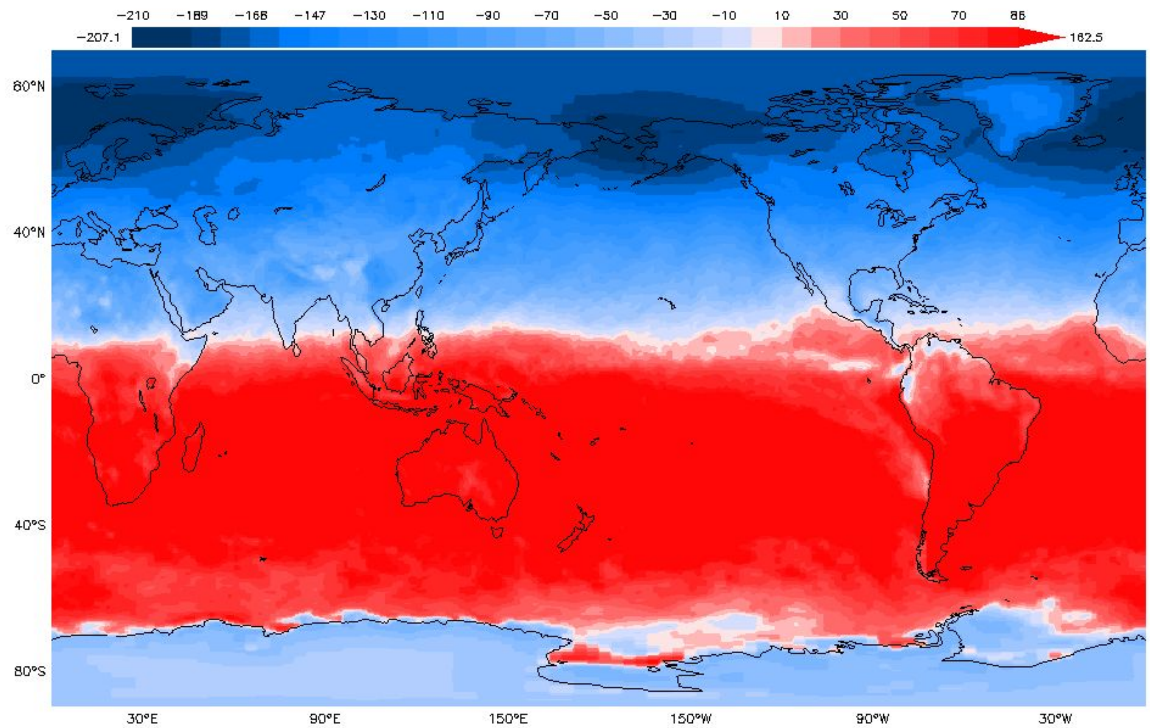
Month	Qualitative	Quantitative
January	e.g., 1) There appears to be a balance of incoming and outgoing radiation at the Equator and at the northern edge of Antarctica. 2.) Antarctica is mostly losing radiation. 3) Greenland is losing less radiation that its surrounding environments at its same latitude.	e.g., 1) Around 10°N, there is a balance whereby there is an apparent balance among absorbing and reflecting energy. 2) The Southern Hemisphere falls mostly in the range of 30 - 162.5 W/m^2. 3)The Northern Hemisphere falls mostly in the range of -30 to -207.1 W/m^2.
February		
March		
April		
May		
June		
July		

Discuss whether the patterns students observe are consistent with your earlier observations.

Top of Atmosphere (TOA) All Sky

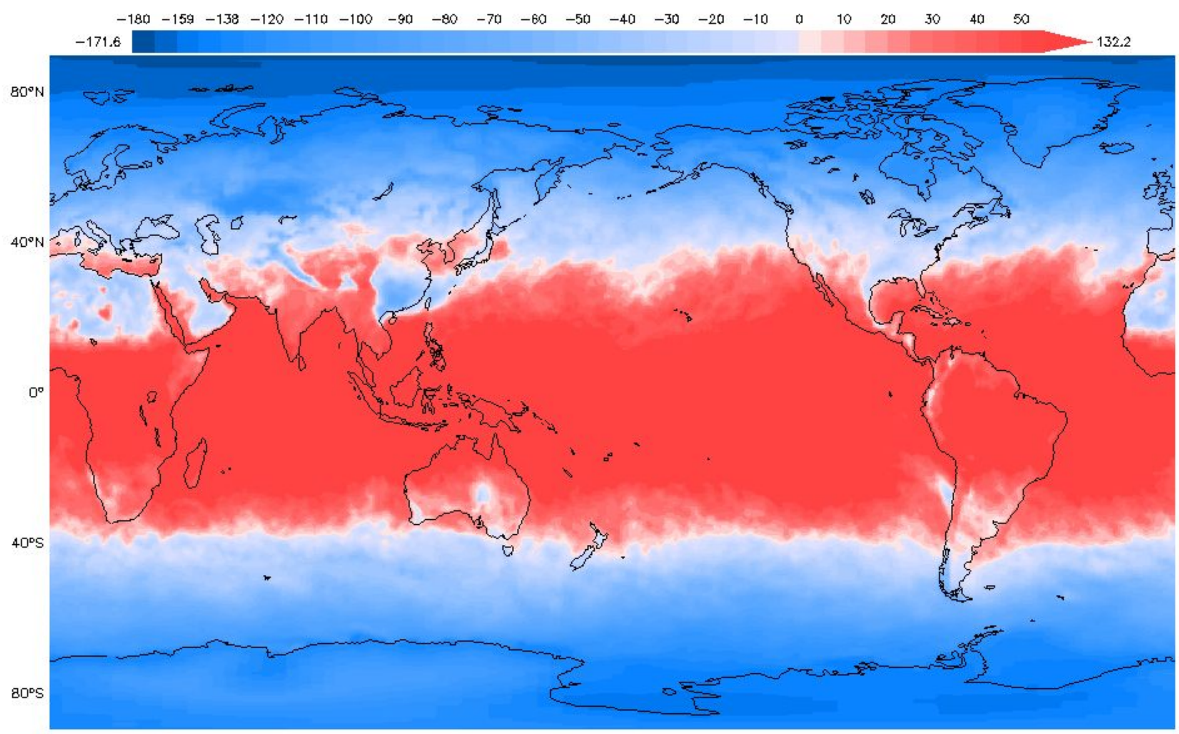
STUDENT PAGE

Watts/m²

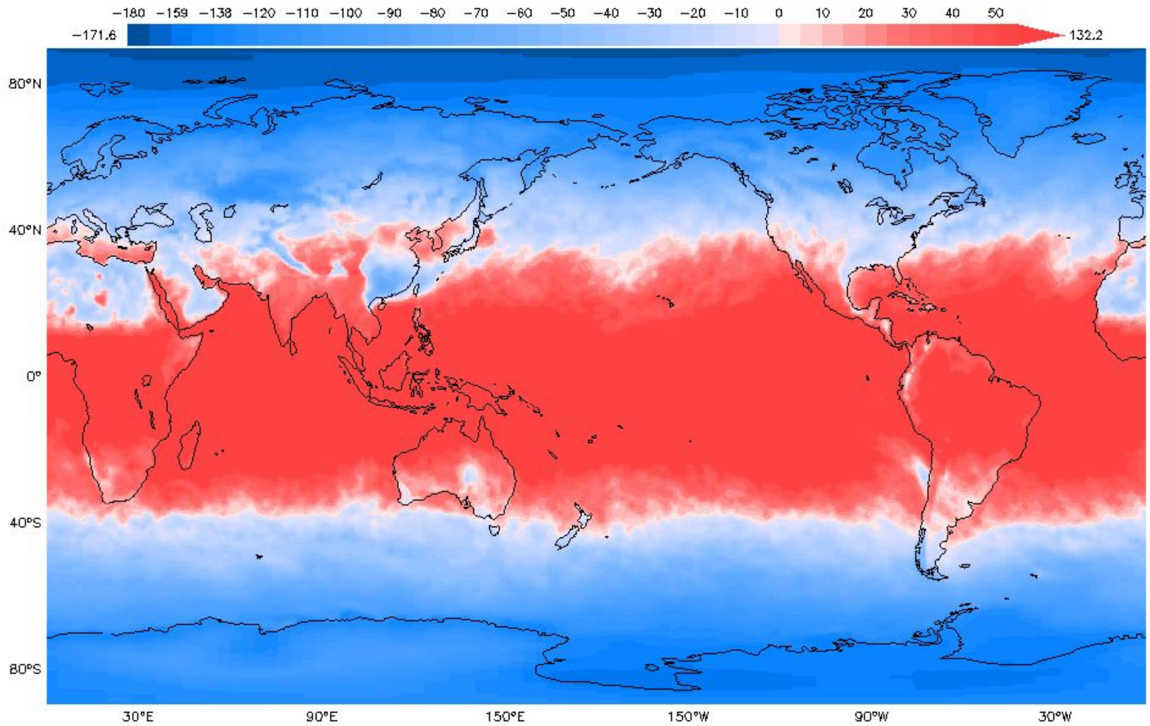


Top of Atmosphere (TOA) All Sky, 15-FEB-2015

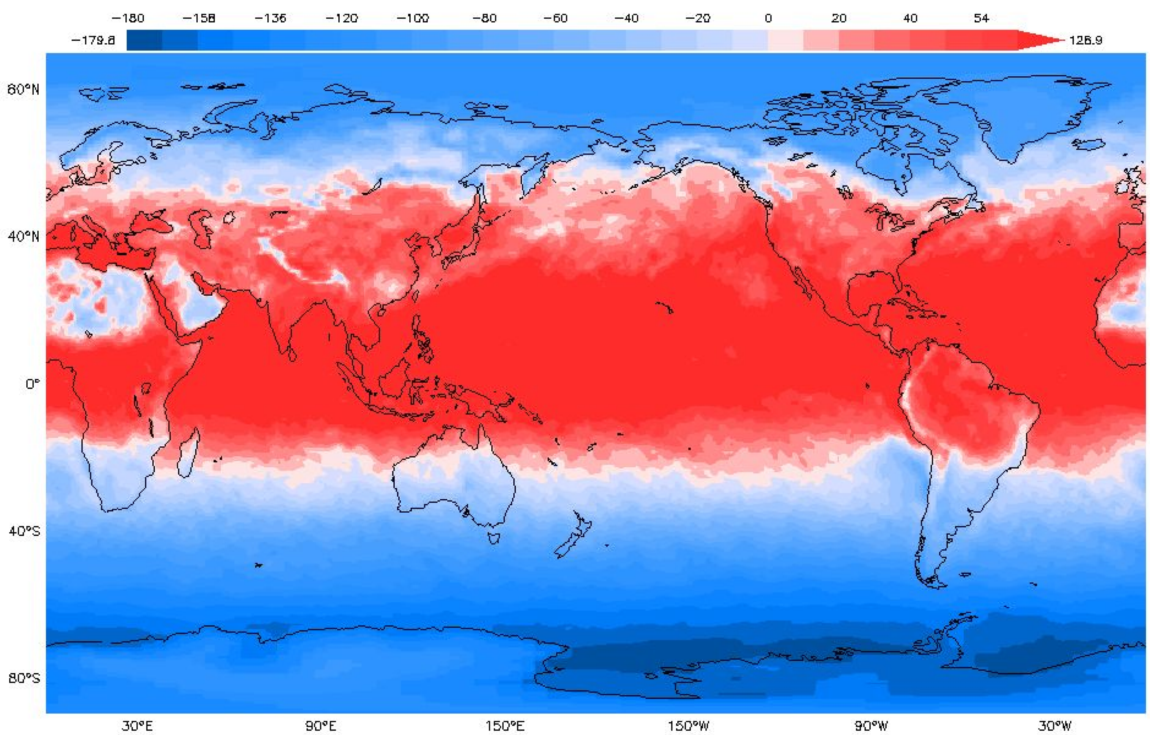
Watts/m²



Top of Atmosphere (TOA) All Sky, 15-MAR-2015 **STUDENT PAGE**
Watts/m²

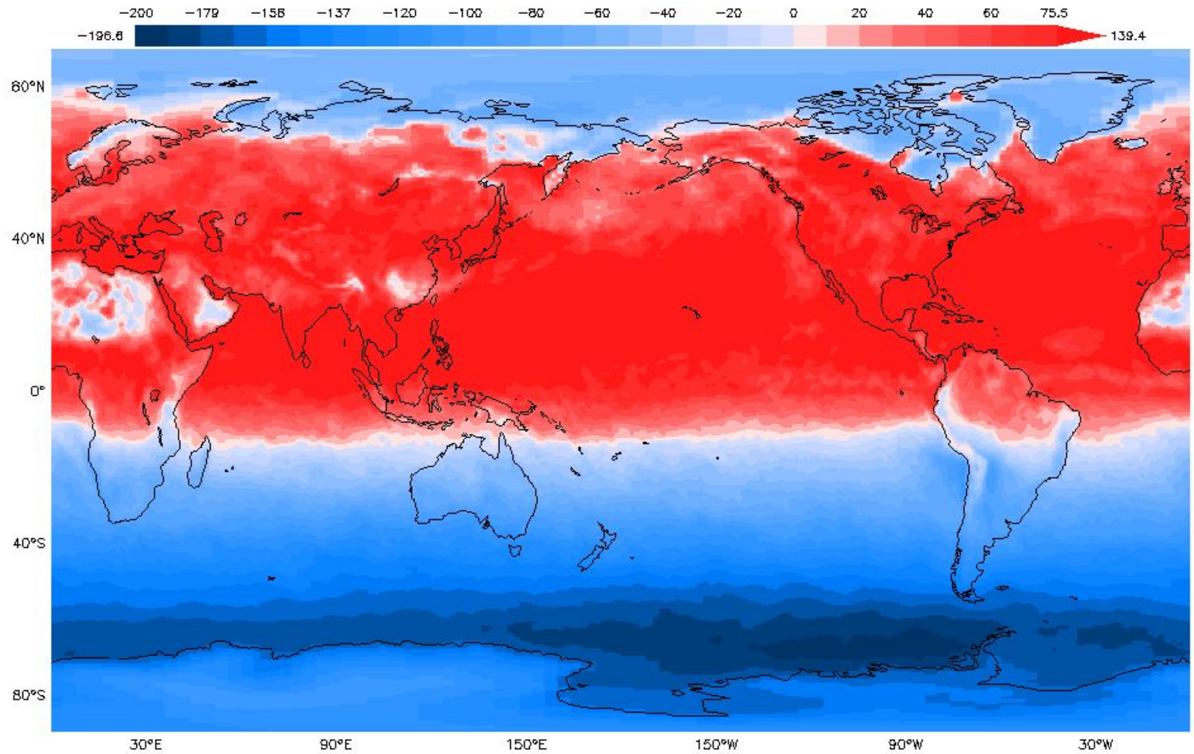


Top of Atmosphere (TOA) All Sky, 15-APR-2015
Watts/m²



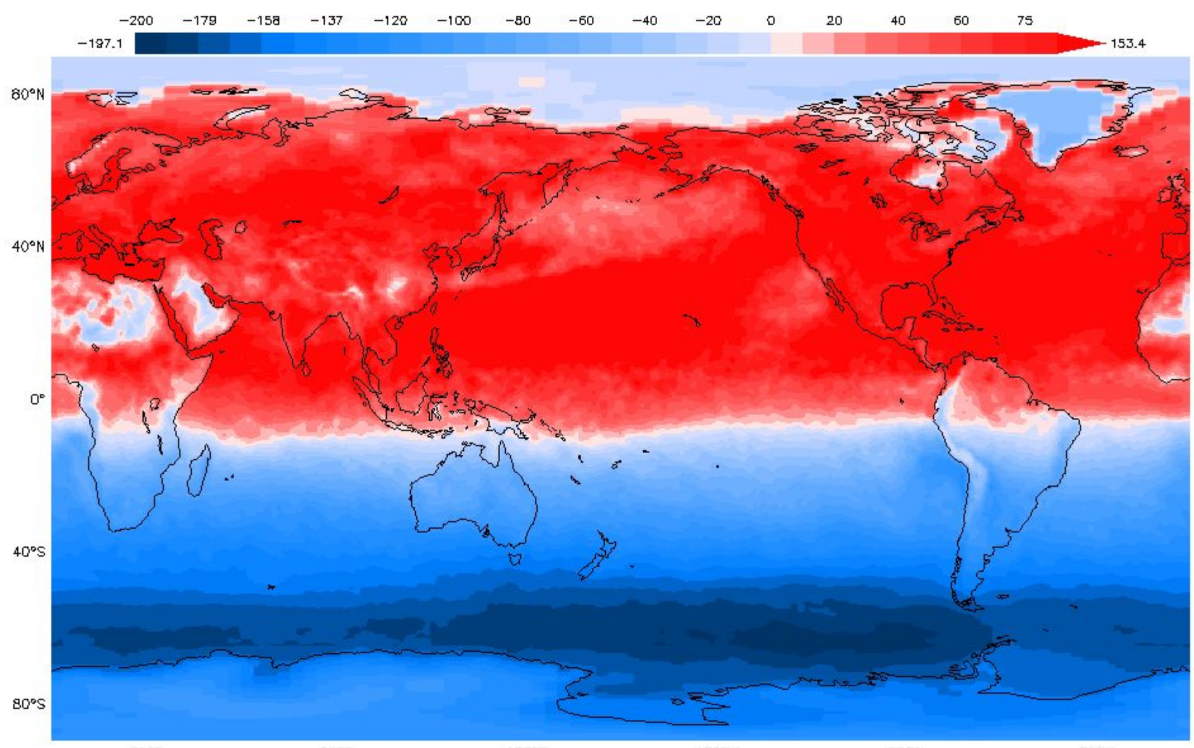
Top of Atmosphere (TOA) All Sky, 15-MAY-2015 **STUDENT PAGE**

Watts/m²



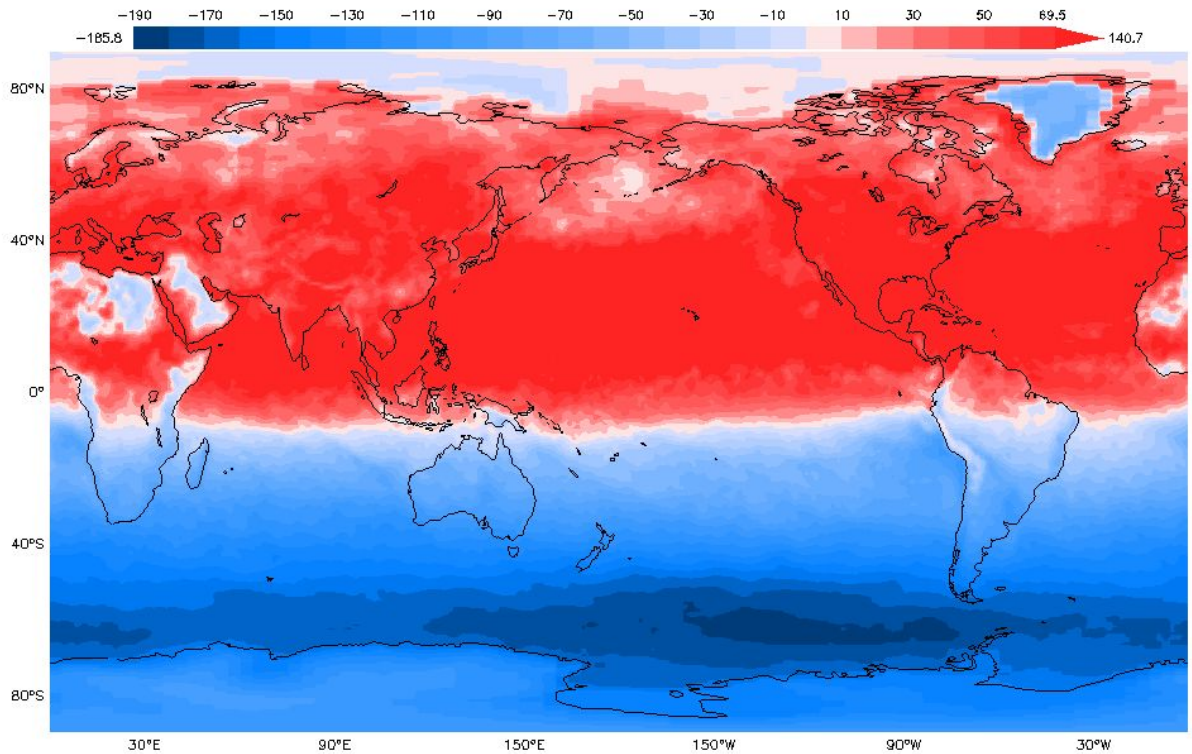
Top of Atmosphere (TOA) All Sky, 15-JUN-2015

Watts/m²



Top of Atmosphere (TOA) All Sky, 15-JUL-2015 **STUDENT PAGE**

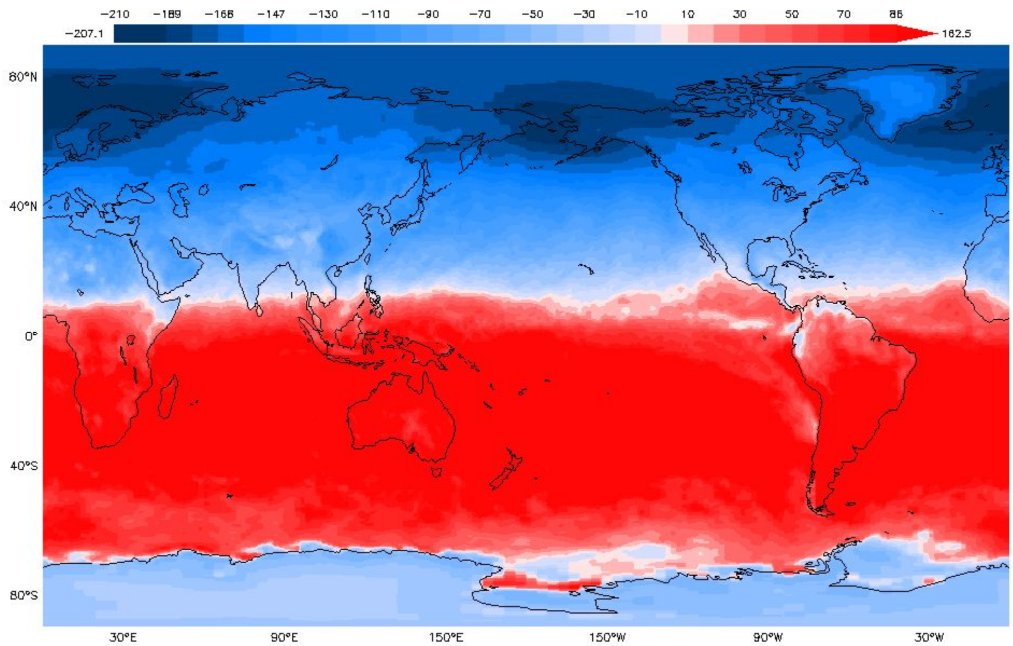
Watts/m²



Top of Atmosphere (TOA) All Sky, 15-JAN-2015

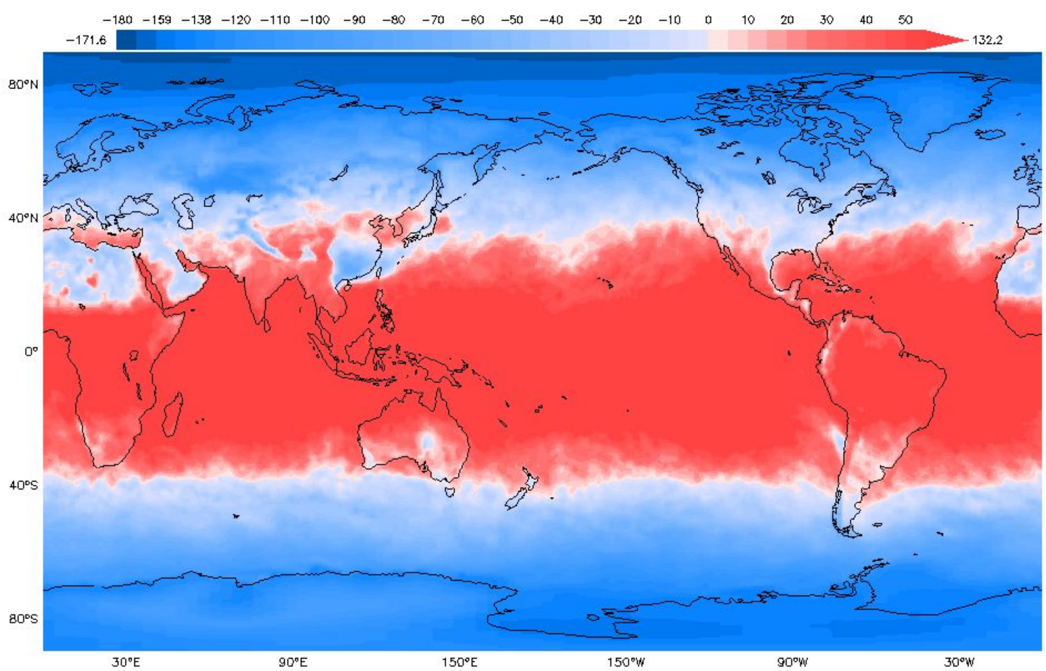
TEACHER KEY

Watts/m²



Top of Atmosphere (TOA) All Sky, 15-FEB-2015

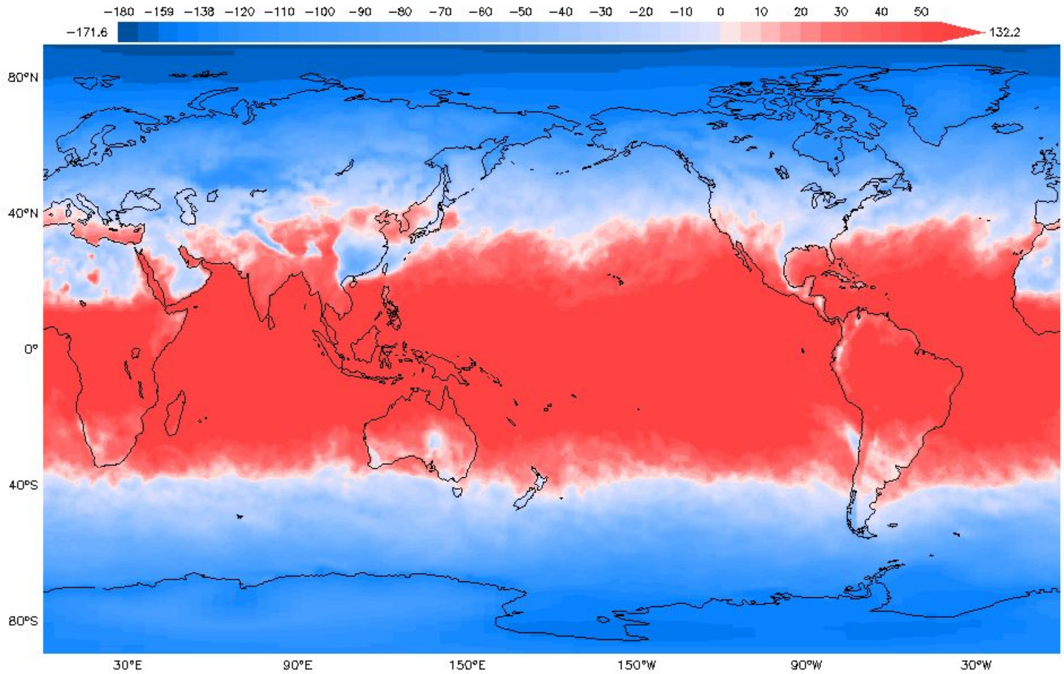
Watts/m²



Top of Atmosphere (TOA) All Sky, 15-MAR-2015

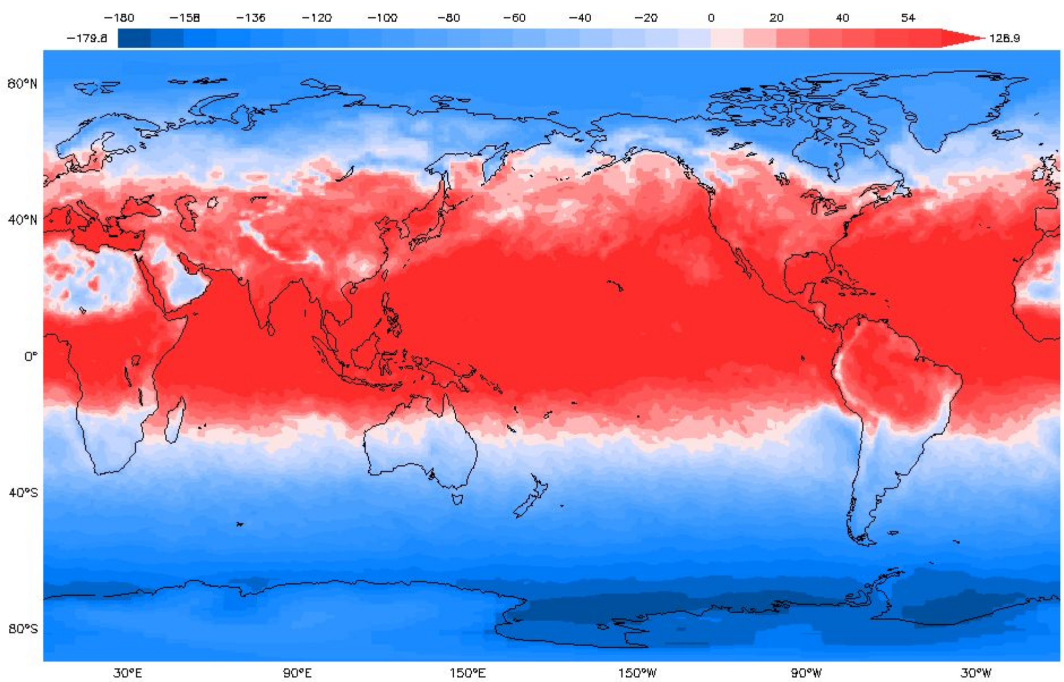
TEACHER KEY

Watts/m²



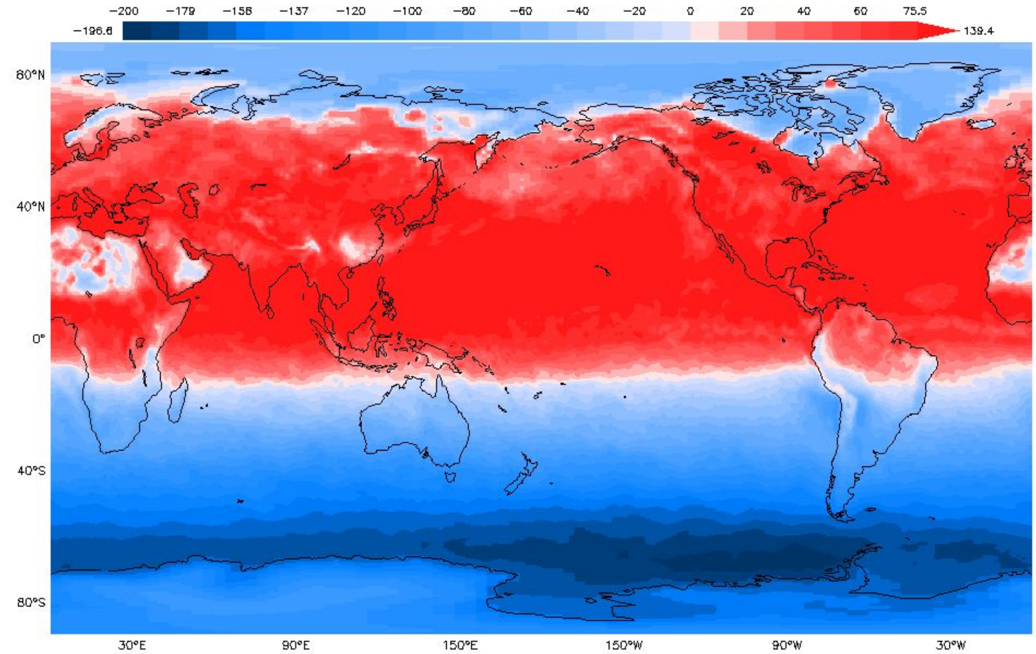
Top of Atmosphere (TOA) All Sky, 15-APR-2015

Watts/m²



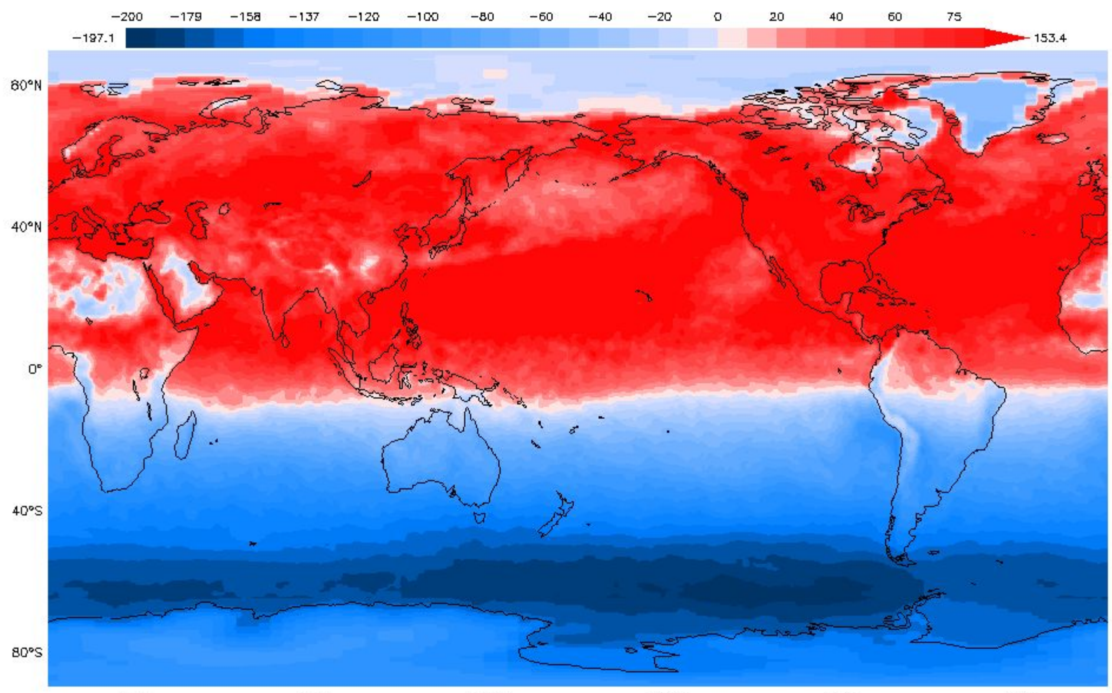
Top of Atmosphere (TOA) All Sky, 15-MAY-2015 **TEACHER KEY**

Watts/m²



Top of Atmosphere (TOA) All Sky, 15-JUN-2015

Watts/m²



Top of Atmosphere (TOA) All Sky, 15-JUL-2015
Watts/m²